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Blizzard

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[54] **EXPANDABLE METAL SEAL FOR A WELL TOOL**

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[58] **Field of Search** 166/120, 121, 134; 277/116.4, 116.6, 116.8, 228, 117-120, 190, 191, 236

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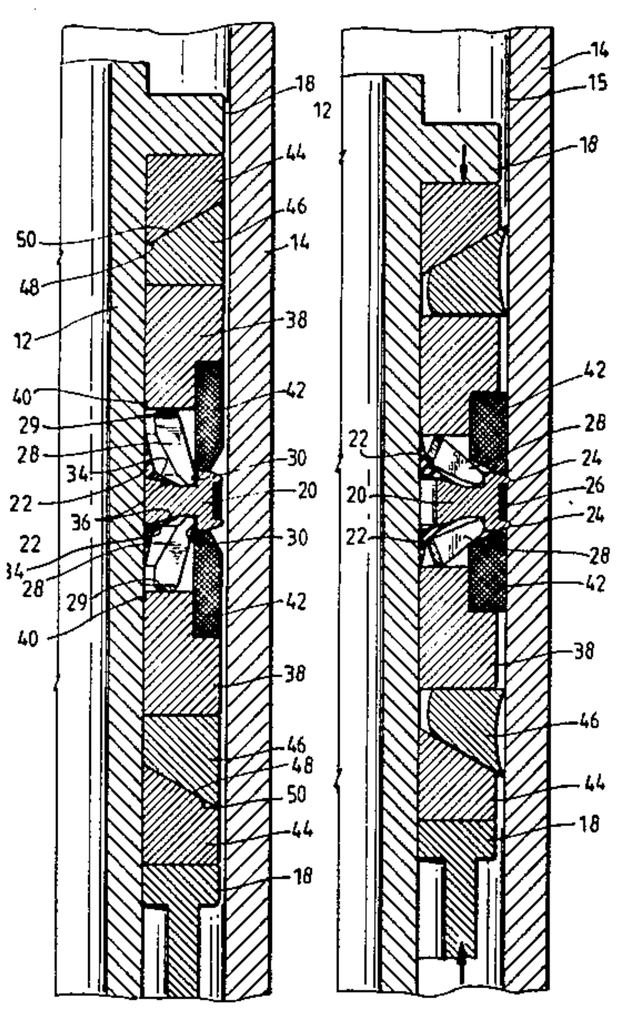
[57] **ABSTRACT**

A metal seal on a well tool for sealing between an inner tubular member and an outer tubular member including an annular metal ring positioned about the inner member having a pair of spaced lips on the outer periphery with a flowable metal insert positioned between the lips. Metal seals are provided on each side of the metal ring sealing between each side of the ring and the inner member. Fingers between the setting mechanism and the metal ring expand the metal ring outwardly upon movement of the setting mechanism. An expandable metal support is positioned on the outside of the setting mechanism adjacent the outer edge of the metal ring for supporting the ring as the ring is set. The setting mechanism includes a pair of expansion rings having coacting tapered faces for increasing the setting force as the temperature increases.

16 Claims, 3 Drawing Figures



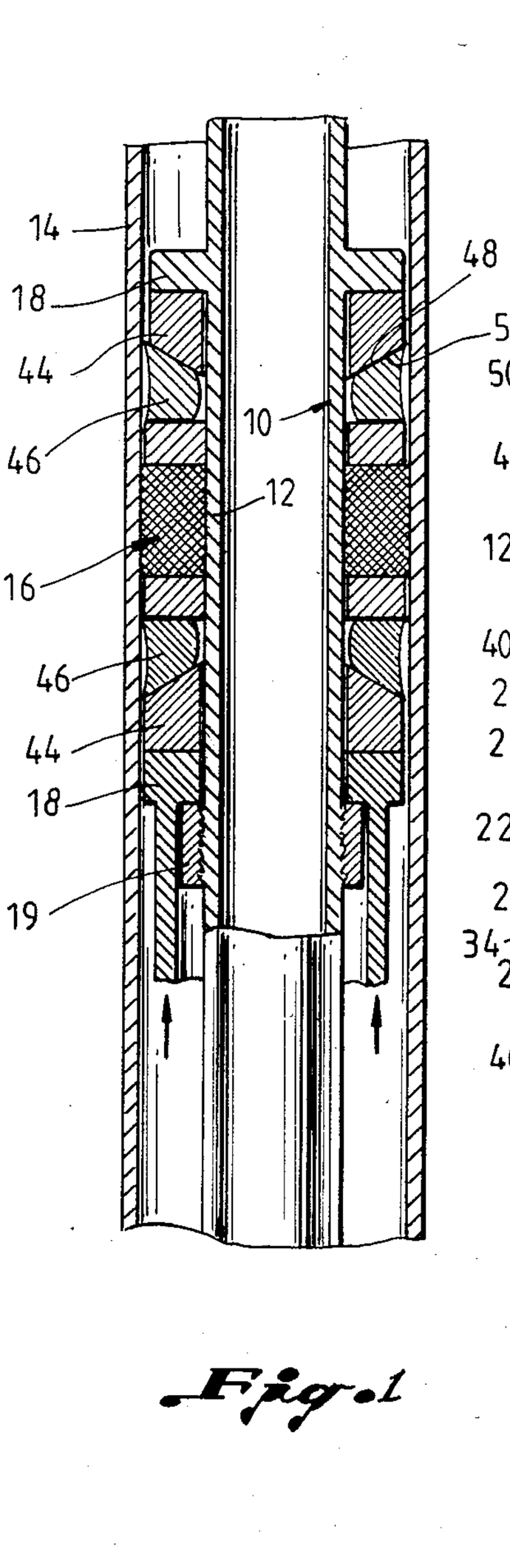


Fig. 1

Fig. 2 A

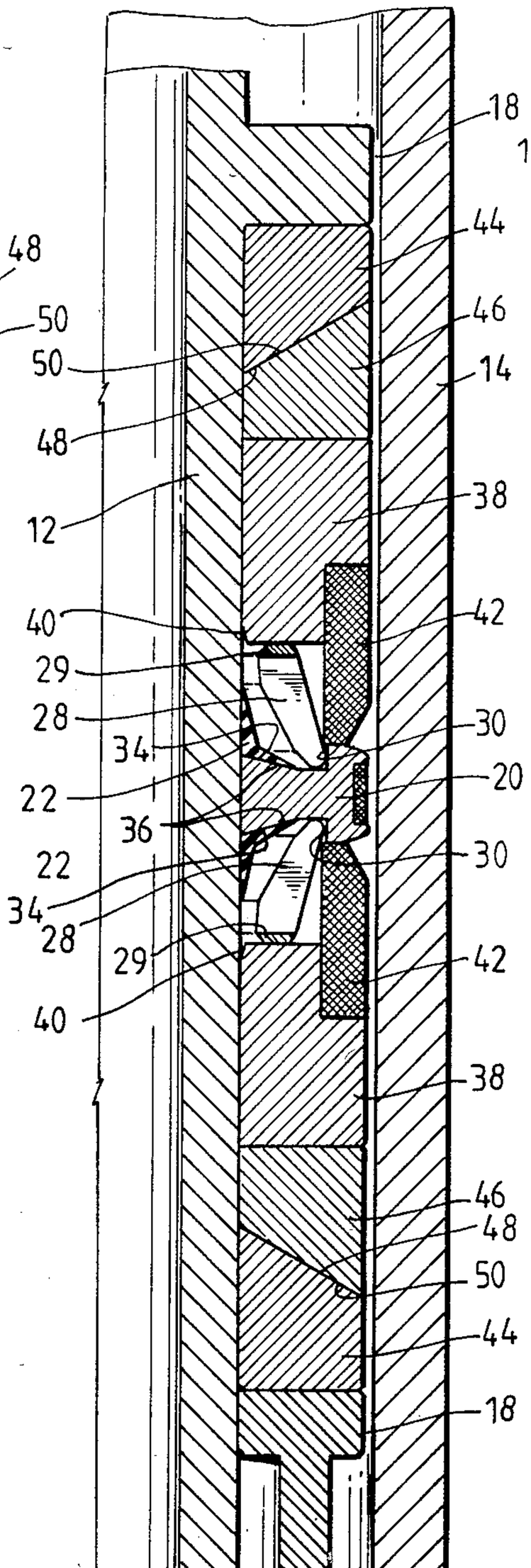
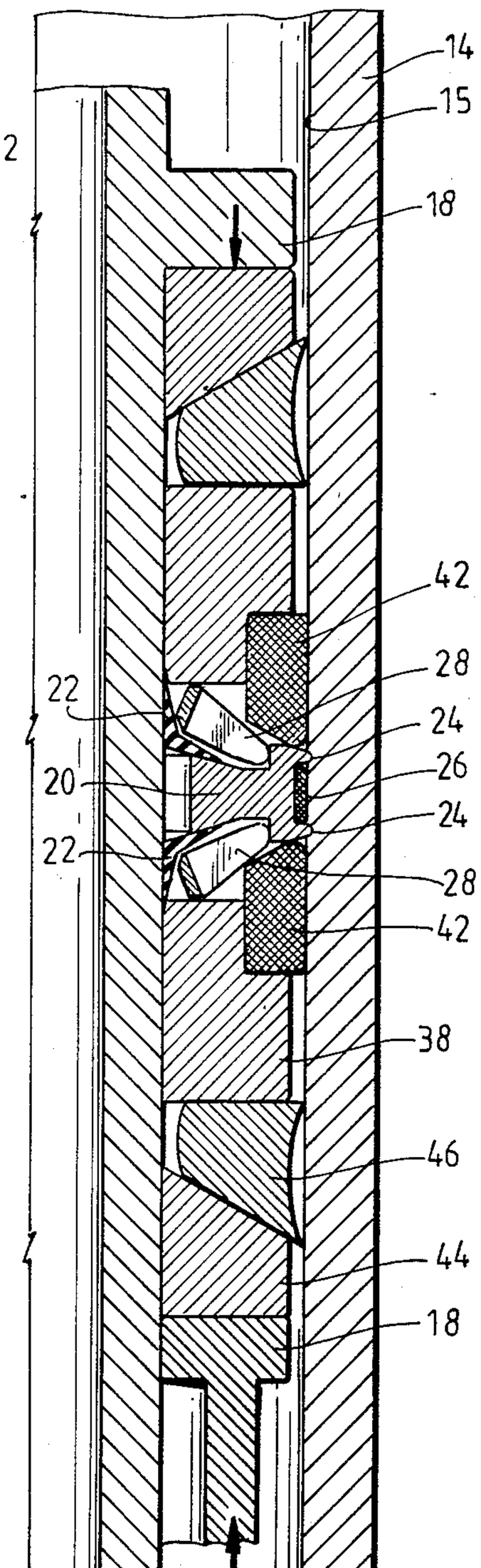


Fig. 2 B



EXPANDABLE METAL SEAL FOR A WELL TOOL

BACKGROUND OF THE INVENTION

Due to the inability of conventional elastomeric components to function well in high temperature or corrosive environments encountered in oil and gas wells, there exists a need for a seal for use in downhole well equipment that will withstand harsh environmental conditions. Such a seal is needed on various well tools such as packers, expansion joints and subs. For example, packers are used in steam injection wells to provide a zone isolating pressure sealing tool that establishes an annular seal between the well casing and the well tubing. In this particular type of application, the steam injection well's operating characteristics create a severe test which conventional sealing materials are unable to meet. In the steam injection process, the injection phase of the operation causes the well equipment to approach temperatures of 650° F., but during the producing phase, the temperatures drop to as low as 80° F. This substantial temperature range, when coupled with pressure differential reversals that commonly occur in downhole environments, subject the well tool seals to conditions which they are unable to overcome. Although semi-elastomers and fiber-type materials such as asbestos and other types of materials such as disclosed in U.S. Pat. No. 4,444,403 have been suggested to combat this problem, their success has been limited.

One feature of the present invention is to provide an expandable metal seal for a well tool and one that will seal in spite of rough surface conditions on the well casing.

Another feature of the present invention is the provision of a series of expansion rings positioned in the seal-setting mechanism for increasing the setting force applied to the seal when the temperature increases. The expansion rings may be a pair of bimetallic expansion rings in which the coefficient of thermal expansion of one of the pair is much greater than the other or the pair of rings may be shape memory effect springs.

SUMMARY

The present invention is directed to a well tool having an expandable seal for sealing off the space between an inner tubular member and an outer tubular member. The seal includes an annular metal ring positioned about the inner tubular member and adapted to expand outwardly for engagement with an outer tubular member and the ring includes a pair of annular spaced lips on the outer periphery of the ring. A flowable metal insert is positioned between the lips for sealing against the outer member. Preferably the insert includes a soft metal filler in a wire mesh substrate which can penetrate the asperities within the surface of the outer tubular member or well casing. Preferably, the lips can protrude into the surface of the well casing and act as a zero clearance backup for preventing extrusion of the insert. Also, because the lips penetrate the rough, typically heavy scaled, surface of the outer member they eliminate any deterimental affect that a rough surface has. Metal seal means are provided on each side of the metal ring sealing between each side of the ring and the inner member. Setting means are provided on each side of the ring for longitudinally moving relative to each other for expanding and moving the metal ring to a set position in engagement with the outer member. Means are provided between each of the setting means and the metal ring for expanding the metal ring radially outward upon movement of the setting means toward each other.

Still a further object of the present invention is wherein expandable metal support means are provided between each of the setting means and the metal ring adjacent to the outer edge of the metal ring for expanding outwardly as the ring is set and engaging and laterally supporting the ring as the ring is set. Preferably the expandable metal support means includes a metal mesh.

Still a further object of the present invention is the provision of a pair of expansion rings between each of the setting means and the annular metal seal. In one form, the rings are bimetallic rings having different coefficients of thermal expansion and each of the expansion rings has a tapered face engaging the tapered face of the other expansion ring. Therefore, an increase in temperature will cause the ring having the higher coefficient to expand more than the other ring thereby increasing the setting force on the seal as the temperature increases. In another form, the rings are shape memory effect ring springs which have tapered engaging faces. After the ring springs are deformed by an axial load they attempt to return to their shape upon an increase in temperature thereby increasing the axial setting force on the seal.

Yet a still further object of the present invention is wherein the annular metal ring includes a head with an inwardly directed shoulder on each side and wherein the means expanding the metal ring outwardly includes a plurality of annularly positioned fingers directed outwardly toward the inwardly directed shoulders on the metal ring. Preferably the fingers on each side of the ring are connected to each other.

Yet a still further object of the present invention is wherein the metal ring includes a tapered surface on each side directed radially outwardly and inwardly for coacting with the metal seal means on each side of the ring for increasing the sealing relationship between the metal ring and the metal seal means as the metal ring is expanded outwardly.

Still a further object of the present invention is wherein each of the setting means includes a tapered surface adjacent the inner tubular member for engaging one of the metal seal means for sealing the one metal seal means against the inner tubular member.

Other and further objects, features and advantages will be apparent from the following description of presently preferred embodiments of the invention, given for the purpose of disclosure and taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematical elevational view showing a seal and setting mechanism of the present invention in the set position,

FIG. 2A is an enlarged elevational view, in cross section, illustrating the seal and setting mechanism of the present invention in the running position, and

FIG. 2B is a view similar to FIG. 2A showing the seal in the set position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the seal and setting mechanism of the present invention may be utilized in various types of well tools for use in sealing off the space between an inner and outer tubular member, the present invention, for pur-

poses of illustration only, will be described in connection with use on a well packer for sealing off the annulus between the well casing and the well tubing.

Referring to the drawings, and particularly to FIG. **1**, the reference numeral **10** generally indicates a portion of a well packer or other well tool having an inner tubular member **12** which is generally connected to the well tubing in an oil and/or gas well inside of an outer tubular member such as a well casing **14**. The packer **10** generally includes seal means generally indicated by the reference numeral **16** for sealing between the inner tubular member **12** and the outer tubular member **14**. Initially, the seal means **16** is retracted away from the member **14** when the packer is being moved downhole into the member or casing **14** and thereafter setting means **18** on each side of the packer **16** is provided for moving longitudinally toward each other for compressing and setting the seal means **16** and thereafter holding the seal **16** in the set position by locking means **19** such as ratchets. Generally, the above described well packer is conventional.

One feature of the present invention is directed to an improved seal means **16**. As previously indicated, conventional sealing materials are unable to cope with temperature and pressure cycling that commonly occur in downhole well environments, particularly in steam injection wells. The present packer **16**, referring now to FIG. **2A**, is a packer which relies on metal sealing elements and does not require any plastic, elastomer or asbestos types of materials. The seal **16** includes an annular metal ring generally indicated by the reference numeral **20** positioned about the inner tubular member **12** and adapted to expand outwardly for engagement with the outer tubular member **14**. The ring **20** may be any suitable metal ring having good tensile, elongation, and hardness properties such as K500 monel. When the ring **20** is in the expanded position, as best seen in FIG. **2B**, the ring **20** will seal and prevent fluid bypass along the interior surface wall **15** of the outer member **14**. Seal means **22** are provided on each side of the ring **20** for sealing between each side of the ring **20** and against the exterior surface of the inner tubular member **12** to prevent fluid bypass along the outer surface of member **12**. Seal means **22** are metal and may be inconel 718.

It is important that the annular metal ring **20** provides a good seal against the interior surface of the outer member **14** since the inner surface **15** of the member **14** may be rough, and in the event that the casing **14** has been in use for a considerable period of time, the condition of the inner surface of the member **14** may have deteriorated. Therefore, the ring **20** is provided with a pair of annularly spaced lips **24** on the outer periphery of the ring **20**. Preferably, the lips **24** are rounded, but sharp enough to protrude into and deform a very small portion of the interior surface **15** of the outer tubular member **14**, as best seen in FIG. **2B**, to enclose a flowable metal insert **26** which is positioned between the lips **24** for sealing against the interior surface of the member **14**. While the insert **26** may be of any flowable metal material and may be solid, it is preferable that the insert **26** have a wire mesh substrate having a soft metal filler. For example, a copper mesh having a lead filler provides a satisfactory seal having the desirable properties of qood elonqation, thermal, and expansion properties. The lips **24** which protrude into the surface **15** of the well casing **14** act as a substantially zero clearance backup for the metal insert **26** for reducing the possibility of extrusion of the insert **26** around the lips **24**. The insert **26** consisting of wire mesh substrate with a soft metal filler penetrates the asperities within the surface **15** to insure sealing against the surface **15** even though the metal surface **15** may be in a rough condition. Preferably, the soft metal filler **26** extends to the outer edge of the lip **24** so that as the lips **24** protrude into the casing surface, the filler material **26** is further highly compressed into the asperities of the casing surface **15**. This effect substantially aids in preventing well bore fluids from passing through the soft metal filler **26** seal surface.

Setting means **18** on each side of the seal means **16** move longitudinally relative to each other for expanding the metal ring **20** outwardly. Suitable means are provided between each of the setting means **18** and the metal ring **20** for expanding the metal ring **20** outwardly into engagement with the tubular member **14**. Such means may include a plurality of annularly positioned fingers **28** directed outwardly toward the metal ring **20**. The metal ring **20** preferably includes a head having a downwardy directed shoulder **30** on each side for engagement with the outer ends of the fingers **28**. Preferably, the plurality of fingers **28** on each side are connected together by a web **29** for ease of positioning. The fingers **28** are made with any suitable metal material such as 410 stainless steel. Thus, as the setting means **18** creates a longitudinal force acting on the web ends **29** of the fingers **28**, the outer ends of the fingers **28** which engage the shoulders **30** transform the setting force into an outward radial force to expand the ring **20** outwardly.

Preferably, the metal ring **20** includes a tapered surface **34** on each side which coacts with each of similar tapered surfaces **36** on the metal seal **22** for increasing the seal between the metal ring **20** and the metal seal means **22** as the ring **20** is moved outwardly.

The setting means **18** may include setting blocks **38** which are preferably provided with a tapered surface **40** adjacent the inner tubular member **12** for engaging one of the metal seals **22** for sealing the metal seals **22** more firmly against the inner member **12**.

Expandable metal support means **42** may be provided between each of the setting means **18** and the metal ring **20** adjacent to the outer edge of the metal ring **20** for supporting the ring **20** as the ring is set. Thus, support means **42** which may be of any flowable solid suitable metal, but are preferably a wire mesh such as inconel and are connected to and supported from the outer surface of the setting blocks **38**. The support members **42** are not required to provide any sealing function, but physically provide a structural support to the outer end of the ring **20** as it is extruded outwardly to insure that it moves radially outwardly and prevent it from tilting.

The metal seal means **16** of the present invention eliminates extrusion of the seal, avoids the use of elastomers, is able to provide a tight seal against rough inner surface existing on the casing or outer tubular member **14** and therefore will have a substantially longer life and greater reliability than conventional seals.

Another feature of the present invention is the provision of utilizing a series of expansion rings for creating an additional setting force on the seal means **16** as the temperature in the seal environment increases. Thus, referring to FIG. **1**, in one form of the invention, a pair of bi-metallic thermal expansion rings **44** and **46** are provided between the seal means **16** and each of the setting means **18**. The expansion rings **44** and **46** differ from one another in that they are made from two differ-

ent materials which vary greatly in their coefficients of thermal expansion. For example only, rings **44** may be of stainless steel and rings **46** may be of aluminum which has a considerably higher thermal coefficient of expansion. Each of the expansion rings **44** and **46** includes a tapered face such as ring **44** having a tapered face **48** and ring **46** having a tapered face **50** with the faces **48** and **50** coacting. During normal setting of the packing means **16**, the axial or longitudinal force transmitted by the setting means **18** is transmitted through the rings **46** and **44** to the seal means **16**. However, in high temperature applications such as occurs in steam injection wells, the rings **44** and **46** will heat up during steam injection and the ring with the greater coefficient of thermal expansion, here rings **46**, will expand more rapidly to provide an increased axial force which increases the setting force supplied to the seal means **16**. This additional force is locked in through the ratchets **19** and results in a greater pressure holding capability of the seal **16**. Of course, the bi-metallic expansion rings may be used in other applications to increase the setting force on other types of seal means than the particular seal means **16** shown herein.

In another form the metal expansion rings **44** and **46** may be shape memory effect ring springs such as sold under the trademark "NITINOL". In one form one of the rings may be nickel-titanium and the other any suitable metal such as stainless steel. An axial force is applied to the rings as the setting piston **18** sets the seal **16** and the shape memory effect ring springs are diametrically deformed. Once the piston **18** is locked in position by the ratchets **19** a high bearing stress is created in tapered interfaces **48** and **50**. A rise in temperature will cause the shape memory effect rings to utilize their unique property by undergoing a transformation of their overall crystal structure and attempt to return to their original shape before any axial forces were applied by the piston **18**. The shape memory effect ring springs, by trying to return to their original shape, exert an amount of additional axial force to the seal means **16** thereby enabling the seal **16** to withstand a greater pressure differential.

The shape memory effect rings are advantageous in that they do not require the relatively large temperature differentials that the different coefficient of thermal expansion rings require for actuation. Of course, either types of the wedge shaped expansion rings may be used to set various types of seals **16** and either type of expansion ring may be used to increase the sealing force in a seal regardless of whether the seal is set by one or two pistons.

The present invention, therefore, in well adapted to carry out the objects and attain the ends and advantages mentioned as well as others inherent therein. While presently preferred embodiments of the invention have been given for the purpose of disclosure, numerous changes and details of construction and arrangement of parts will readily suggest themselves to those skilled in the art and which are encompassed within the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a well tool having an expandable seal sealing off the space between an inner tubular member and an outer tubular member, the improvement in said seal comprising,

an annular metal ring positioned about the inner tubular member and adapted to expand outwardly for engagement with an outer tubular member, said ring including a pair of annular spaced lips on the outer periphery of the ring,

a flowable metal insert positioned between said lips for sealing against the outer member,

metal seal means on each side of the metal ring for sealing between each side of the ring and the inner member,

setting means on each side of the ring for longitudinally moving toward each other for setting the metal ring, and

outwardly movable metal means between each of the setting means and the metal ring for expanding the metal ring radially outward upon movement of the setting means toward each other.

2. The apparatus of claim **1** including,

expandable metal support means between each of the setting means and the metal ring adjacent the outer edge of the metal ring for expanding outwardly as the ring is set and engaging and laterally supporting the ring as the ring is set.

3. The apparatus of claim **2** wherein the metal support means includes,

a metal mesh.

4. The apparatus of claim **1** wherein the setting means includes,

a pair of bi-metallic expansion rings which have different coefficients of thermal expansion, each of said expansion rings having a tapered face engaging the tapered face of the other expansion ring.

5. The apparatus of claim **1** wherein the means expanding the metal ring radially outward includes,

a plurality of annularly positioned fingers directed outwardly toward the metal ring.

6. The apparatus of claim **1** wherein the metal insert includes,

a metal mesh filled with a flowable metal.

7. The apparatus of claim **1** wherein the lips are sharp enough to penetrate into the surface of the outer member.

8. The apparatus of claim **1** wherein the annular metal ring includes,

a head with an inwardly directed shoulder on each side for engaging the means for expanding the metal ring.

9. The apparatus of claim **1** wherein the metal ring includes a tapered surface on each side directed radially outwardly and inwardly for coacting with each of the metal seal means for increasing the sealing relationship between the metal ring and said metal seal means as the metal seal ring is moved outwardly.

10. The apparatus of claim **1** wherein each setting means includes,

a tapered surface adjacent the inner tubular member for engaging one of the metal seal means for sealing the one metal seal means against the inner tubular member.

11. In a well tool having an expandable seal for-sealing off the space between an inner tubular member and an outer tubular member, the improvement in said seal comprising,

an annular metal ring positioned about the inner tubular member and adapted to expand outwardly for engagement with an outer tubular member, said ring including a pair of annular spaced lips on the outer periphery of the ring,

a flowable metal insert positioned between said lips for sealing against the outer member,

metal seal means on each side of the metal ring sealing between each side of the ring and the inner member, said ring including an inwardly directed shoulder on each side,

setting means on each side of the ring on the side of each of the metal seal means opposite the metal ring for longitudinally moving toward each other for setting the metal ring,

outwardly movable metal means between each of the setting means and the metal ring and engagable with the inwardly directed shoulders for expanding the metal ring radially outward upon movement of the setting means toward each other, and

expandable metal support means positioned on the outer edge of each of the setting means and adjacent the outer edge of the metal ring for expanding outwardly as the ring is set and engaging and laterally supporting the ring as the ring is set.

12. The apparatus of claim **11** wherein the metal insert includes a metal mesh filled with a flowable metal.

13. The apparatus of claim **11** wherein the expandable metal support includes a metal mesh.

14. The apparatus of claim **11** wherein the means for expanding the metal ring radially outward includes,

a plurality of annularly positioned and connected fingers directed outwardly toward the metal ring.

15. The apparatus of claim **11** wherein the metal ring includes a tapered surface on each side directed radially outwardly and inwardly for coacting with each of the metal seal means for increasing the sealing relationship between the metal ring and said metal seal means as the metal seal ring is moved outwardly.

16. The apparatus of claim **11** wherein the setting means includes,

a pair of thermal expansion rings, each of said expansion rings having a tapered face engaging the tapered face of the other expansion ring.

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